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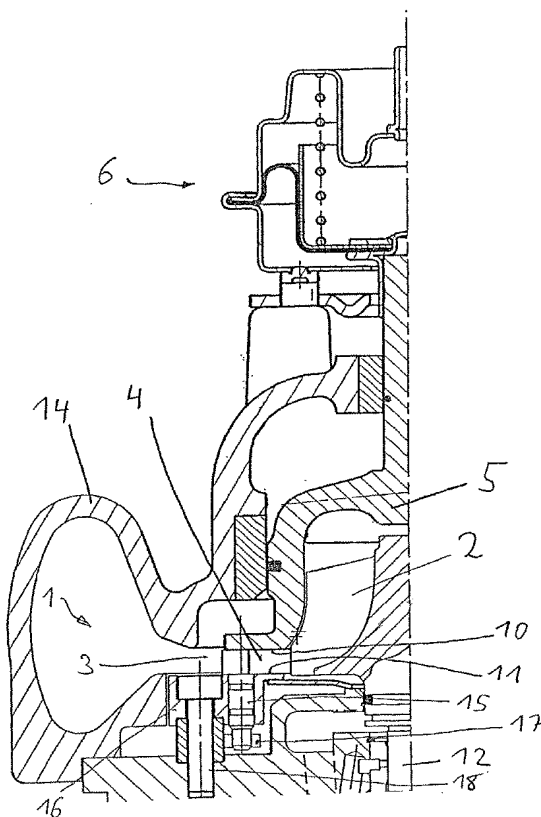
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(54) Title: VARIABLE NOZZLE DEVICE FOR A TURBOCHARGER AND METHOD FOR OPERATING THE SAME



(57) Abstract: A variable nozzle device (1) for a turbocharger comprises an annular nozzle (3) formed between an inner wall (11) and an outer wall (10), and an annular arrangement of adjustable vanes (4) interposed in the nozzle (3) for defining a plurality of nozzle passages, wherein the nozzle (3) is adjustable by controllably adjusting the vanes (4) and by controllably varying an axial clearance between the outer wall (10) and the vanes (4).

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European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

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**Description**

The present invention generally relates to a variable nozzle device for a turbocharger, and also to a method for operating a variable nozzle device for a turbocharger.

A turbocharger having a conventional variable nozzle device is known from US-4 643 640. The nozzle device comprises an annular nozzle between an inner wall and an outer wall, and an annular arrangement of adjustable vanes interposed in the nozzle for defining a plurality of nozzle passages, wherein the nozzle is adjustable by controllably pivoting the vanes between the inner and outer walls.

Thereby, the nozzle passages vary the gas flow to the turbine, i.e. the gas flow area of the annular nozzle. The annular nozzle is formed by a nozzle ring which forms the inner wall, a shroud which forms the outer wall, and the pivotable vanes. There has to be a clearance or a gap between the pivotable vanes and the shroud so as to hold the vanes pivotable. The size of such clearance is usually limited to both ensure performance level and prevent the vanes from sticking to the shroud.

It is the object of the present invention to provide a variable nozzle device for a turbocharger and a method for operating a variable nozzle device which allow an improved turbine performance.

This object is achieved by a variable nozzle device having the features of claim 1 or 10, and by a method of operating a variable nozzle device having the features of claim 7. The invention is further developed by the dependent claims.

Fig. 1 shows a partial cross-section of a nozzle device for a turbocharger according to a first embodiment of the present invention;

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Figs. 2A and 2B show a cross-sectional view and a plan view of the nozzle device according to the first embodiment of the present invention, respectively, wherein the nozzle is fully closed;

Figs. 3A and 3B show a cross-sectional view and a plan view of the nozzle device for a turbocharger according to the first embodiment of the present invention, respectively, wherein the nozzle is half open;

Figs. 4A and 4B show a cross-sectional view and a plan view of the nozzle device for a turbocharger according to the first embodiment of the present invention, respectively, wherein the nozzle is fully opened;

Fig. 5 shows a view of a nozzle device including a vane pivoting mechanism for a turbocharger according to a second embodiment of the present invention; and

Fig. 6 shows another view of the vane pivoting mechanism depicted in Fig. 5.

A first embodiment of a nozzle device 1 according to the present invention is described with reference to Fig. 1.

The nozzle device 1 shown in Fig. 1 is to be incorporated in a turbocharger. A conventional turbocharger comprises an exhaust gas driven turbine 2 mounted to a rotatable shaft 12 having a compressor impeller thereon, a turbine housing 19 forming a volute therein for directing an exhaust gas flow from an engine (not shown) to the turbine 2 through an annular nozzle 3. The annular nozzle 3 is defined between an inner and an outer wall 11, 10. Interposed in the nozzle 3, there is an annular arrangement of adjustable vanes 4 for defining a plurality of nozzle passages. The nozzle 3 is adjustable by controllably

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adjusting the vanes 4 between the inner and outer walls 11, 10 so as to vary the geometry of the nozzle passages.

The vanes 4 are adjusted by means of a vane pivoting mechanism which is described with reference to the figures. The vane pivoting mechanism consists of a vane pin 15, a vane arm 17, a nozzle ring 16, an unisson ring 14 and an actuating member 18. The vane 4, the vane pin 15 and the vane arm 17 are rigidly connected to each other. The nozzle ring 16 is stationary, while the main arm 18 is pivotable with respect to the unisson ring 14.

When the main arm 18 rotates the unisson ring 14, as it is shown in Figs. 3A and 3B, the vanes 4 are pivoted.

In this embodiment, the inner wall 11 of the nozzle ring 16 is formed by an annular ring-shaped plate. Preferably, the annular ring-shaped plate acts like a heat shield. However, the inner wall 11 may also be formed by any part of the turbine housing.

The nozzle device 1 according to the invention comprises a hollow shaft 5 (a hollow piston) surrounding the turbine 2 and defining the outer wall 10 of the annular nozzle 3, the hollow shaft 5 being axially movable to and from the vanes 4.

The hollow shaft 5 is used to cancel the functional gap (right and left side of the vane 4) and increase the turbine stage efficiency all along the engine range until pivoting vane 4 are fully open, then the sliding piston 5 starts to open from the vane top, increasing the passage width and turbine flow capacity, the hollow shaft 5 will be axially moved away from the vanes 4 so as to prevent the vanes 4 from sticking to the outer wall 10 defined by the hollow shaft 5.

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In this construction, commonly known elements once required in the prior art for adjusting the clearance to approximately zero can be omitted.

The movement of the hollow shaft 5 is effected by an actuator 6 which is, for instance, a pneumatic actuator.

Preferably, the hollow shaft 5 comprises an axial slit (not shown) forming a bypass for exhaust gas which does not pass through the annular nozzle 3.

Preferably, the nozzle device 1 is operated by means for operating the hollow shaft 5 in such a manner that the hollow shaft 5 is moved away from the vanes 4 as an operational rotational speed of the turbocharger increases, and that the hollow shaft 5 is moved to the vanes 4 as the operational rotational speed of the turbocharger decreases.

The operation of the nozzle device 1 will be explained below in more detail with reference to the Figs. 2A-2B, 3A-3B and 4A-4B.

As it is shown in Figs. 2A and 2B, in a low rotational speed range of the turbocharger, the nozzle passages are closed by the vanes 4. At the same time, the hollow shaft 5 is initially in contact with the vanes 4 so as to cancel the clearance between the vanes 4 and the walls 10. Thereby, the turbine stage exhibits a improved efficiency even in the low rotational speed range of the turbocharger.

As it is shown in Figs. 3A and 3B, in medium rotational speed ranges, the nozzle passages are opened by the vanes 4 by pivoting the vanes 4, but the hollow shaft 5 is still kept in the position close to the vanes 4. Thereby, the nozzle is half-opened.

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As it is shown in Figs. 4A and 4B, in high rotational speed ranges, the nozzle passages are further kept open by the vanes 4. At the same time, the hollow shaft 5 is moved away from the vanes 4. Thereby, the vanes 4 are prevented from sticking on the outer wall 10 defined by the hollow shaft 5.

Advantageously, the flow capacity is increased such that an engine backpressure in the high rotational speed range of the turbine 2 is reduced.

If the hollow shaft 5 is additionally provided with the slit for forming the bypass, the flow capacity is further increased such that the engine backpressure in the high rotational speed range of the turbine 2 is further reduced.

The timing of moving the hollow shaft 5 and the timing of pivoting the vanes 4 may be tuned so as to achieve an optimum performance of the turbocharger, i.e. an optimum turbine efficiency, a large boost and a low backpressure. As it is described above, when the rotational speed increases, the vanes 4 are first adjusted to open the nozzle passages. When the rotational speed is further increased, the hollow shaft 5 is then moved away from the vanes 4.

In general, it is possible to start moving the hollow shaft 5 away from the vanes 4 and to start pivoting the vanes 4 for enlarging the gas flow area of the annular nozzle 3 either independently (separately) or simultaneously. It is also possible to start moving the hollow shaft 5 to the vanes 4 and to start pivoting the vanes 4 for reducing the gas flow area of the annular nozzle 3 either independently or simultaneously.

In a similar manner, it is possible to stop moving the hollow shaft 5 away from the vanes 4 and to stop pivoting the vanes 4 for enlarging the gas flow area of the annular nozzle 3 either independently or simultaneously, and/or to stop moving the

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hollow shaft 5 to the vanes 4 and to stop pivoting the vanes 4 for reducing the gas flow area of the annular nozzle 3 either independently or simultaneously.

The first embodiment can be modified in that, instead of the hollow shaft 5, any means can be provided which comprises a variable outer wall for varying the gas flow to the turbine.

The embodiment according to the present invention achieves a large boost in the low rotational speed range due to the cancelled clearance (also called "zero gap") between the vanes 4 and the outer wall 10 defined by the hollow shaft 5, when the hollow shaft 5 is in a position closest to the vanes 4.

In middle and high rotational speeds of the engine, the backpressure is reduced by moving the hollow shaft 5 away from the vanes 4. The backpressure may be further decreased by the bypass for exhaust gas, which does not pass through the annular nozzle 3.

A second embodiment according to the present invention shows a nozzle device including a vane pivoting mechanism as it is described with reference to Figs. 5 and 6.

The vane pivoting mechanism for a variable nozzle device 1 for a turbocharger comprises at least one vane 4 attached to a gear 7 and a gear device 8 being in engagement with the gear 7 so that the vane 4 is pivoted when the gear device 8 is moved relatively to the gear.

Preferably, the vanes 4 are connected via a rod (not shown) with the respective gear wheels 7. The rods pass through the inner wall 11 such that they are rotatably supported by the inner wall 11. For pivoting the vanes 4, there are two alternative modes. In the first mode, the inner wall 11 is rotated while the gear



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ring 8 is fixed. In the second mode, the gear ring 8 is rotated while the inner wall 11 is fixed.

The provision of the gear wheels 7 and the gear ring 8 for pivoting the vanes 4 is simpler than the prior art arrangement, since many elements can be omitted which were necessary in the prior art, for instance arm vanes, rollers, pins, unisson rings, etc.

Instead of the gear wheel 7, any element having a gear or a toothing can be provided. It is further conceivable that the gears 7 and the ring 8 are in a frictional engagement instead of a meshing engagement.

The embodiments described herein are to be considered as illustrative and they do not limit the scope of protection. The invention can be modified within the scope of the attached claims.

**Claims**

1. A variable nozzle device (1) for a turbocharger comprising:  
an annular nozzle (3) formed between an inner wall (11) and an outer wall (10), and  
an annular arrangement of adjustable vanes (4) interposed in the nozzle (3) for defining a plurality of nozzle passages,  
wherein the nozzle (3) is adjustable by controllably adjusting the vanes (4) and by controllably varying an axial clearance between the outer wall (10) and the vanes (4).
2. A variable nozzle device (1) according to claim 1,  
wherein the outer wall (10) is axially moved to and from the vanes (4) by an actuator, preferably a pneumatic actuator (6).
3. A variable nozzle device (1) according to claim 2,  
wherein the axial movement of the outer wall (10) to the vanes (4) is limited by a spacer which defines a minimum axial clearance between the vanes (4) and the outer wall (10).
4. A variable nozzle device (1) according to any one of claims 1 to 3,  
wherein the outer wall (10) is defined by a hollow shaft (5) which comprises an axial slit forming a bypass for exhaust gas which does not pass through the nozzle (3).
5. A variable nozzle device (1) according to any one of claims 2 to 4,  
comprising means for operating the axial movement of the outer wall (10) in such a manner that the outer wall (10) is moved away from the vanes (4) as an operational rotational speed of the turbocharger increases.
6. A variable nozzle device (1) according to any one of claims 2 to 5,

comprising means for operating the axial movement of the outer wall (10) in such a manner that the outer wall (10) is moved to the vanes (4) as an operational rotational speed of the turbocharger decreases.

7. A method for operating a variable nozzle device (1) for a turbocharger comprising a plurality of vanes (4) arranged in a nozzle (3) defined between an inner wall (11) and an outer wall (10), the vanes (4) forming nozzle passages, the method comprising the steps of:

adjusting the nozzle passages by controllably adjusting the vanes (4), and

varying an axial clearance between the outer wall (10) and the vanes (4) by axially moving the outer wall (10) to and from the vanes (4).

8. A method for operating a variable nozzle device (1) for a turbocharger according to claim 7,

**characterized by the following steps:**

increasing the axial clearance between the outer wall (10) and the vanes (4) as the operational rotational speed of the turbocharger increases; and

decreasing the axial clearance between the outer wall (10) and the vanes (4) as an operational rotational speed of the turbocharger decreases.

9. A method for operating a variable nozzle device (1) for a turbocharger according to claim 7 or 8, wherein

the step of increasing the axial clearance between the outer wall (10) and the vanes (4) starts and/or stops either independently from or simultaneously with a step of pivoting the vanes (4) for enlarging the gas flow area of the annular nozzle (3); and/or

the step of decreasing the axial clearance between the outer wall (10) and the vanes (4) starts and/or stops either independently from or simultaneously with a step of pivoting the

vanes (4) for reducing the gas flow area of the annular nozzle (3).

10. A vane pivoting mechanism for a variable nozzle device (1)  
5 of a turbocharger comprising:

at least one vane (4) attached to a gear (7) and a gear device (8) being in engagement with the gear (7) so that the vane (4) is pivoted when the gear device (8) is moved relatively to the gear (7).

Fig. 1

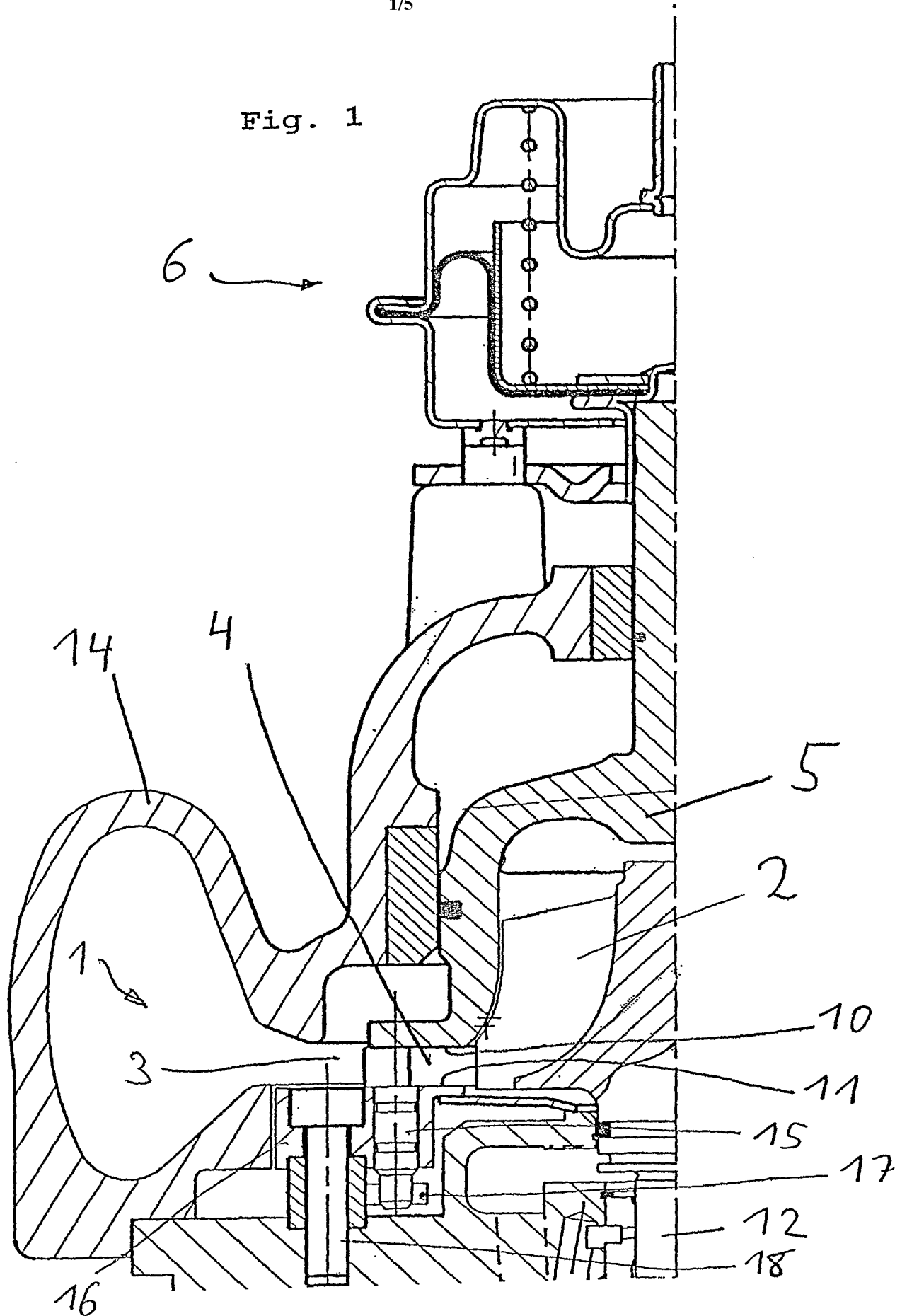


Fig. 2A

Fully closed

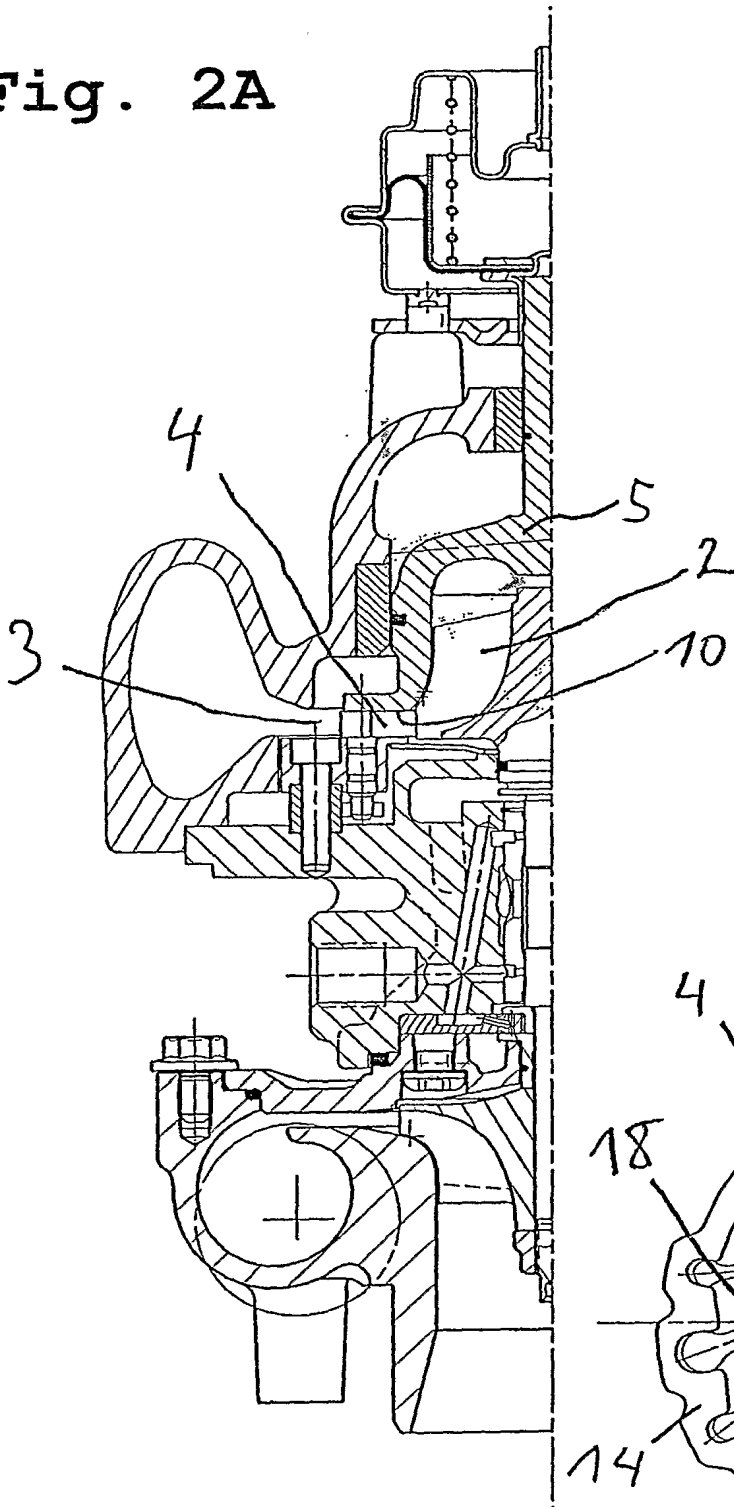
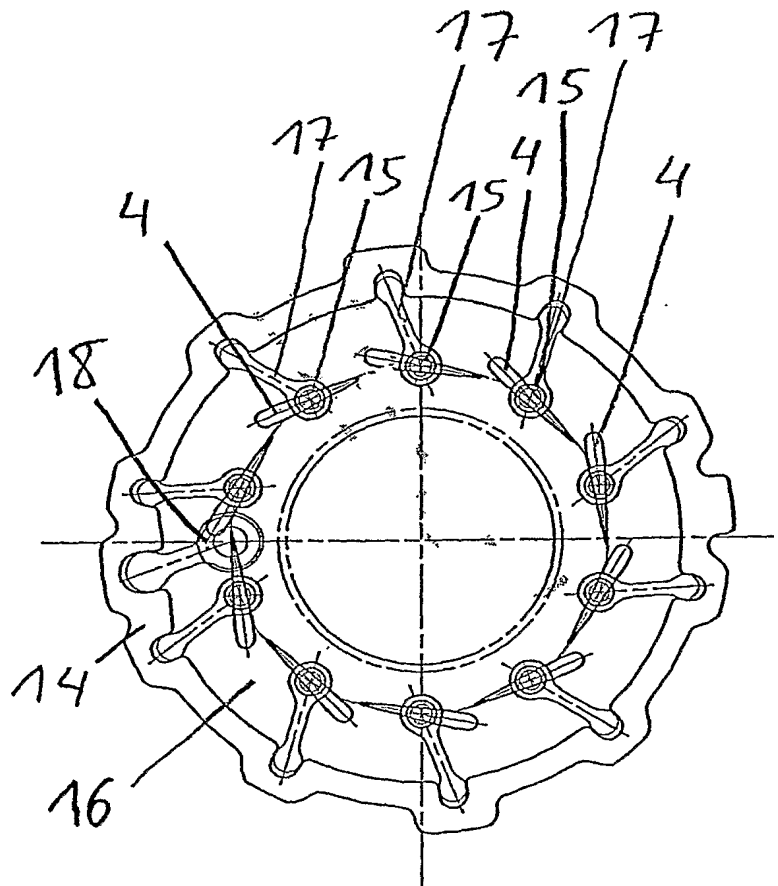
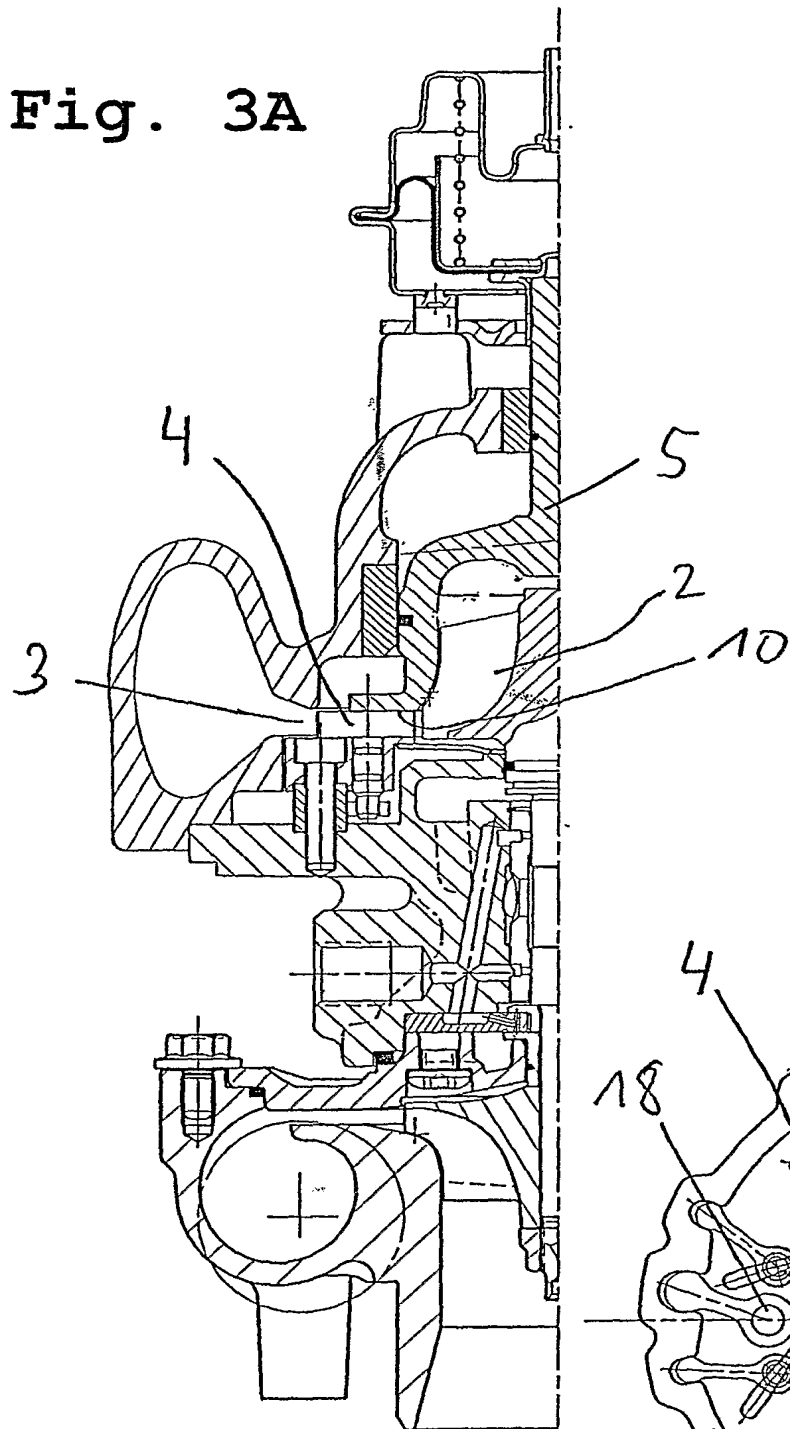


Fig. 2B

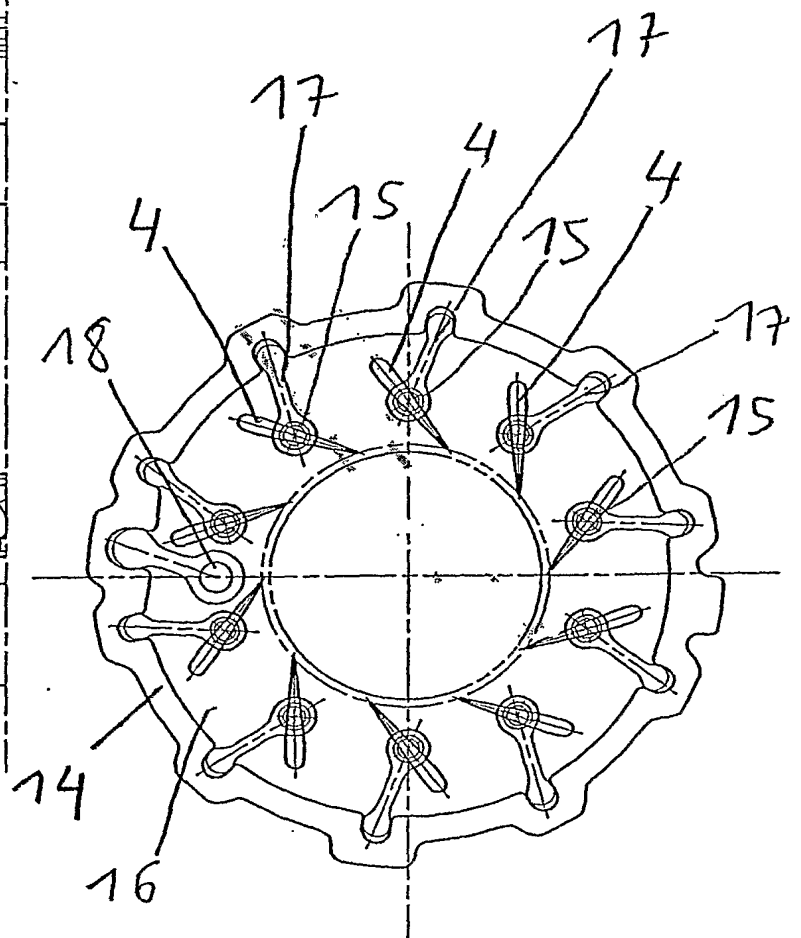


**Fig. 3A**

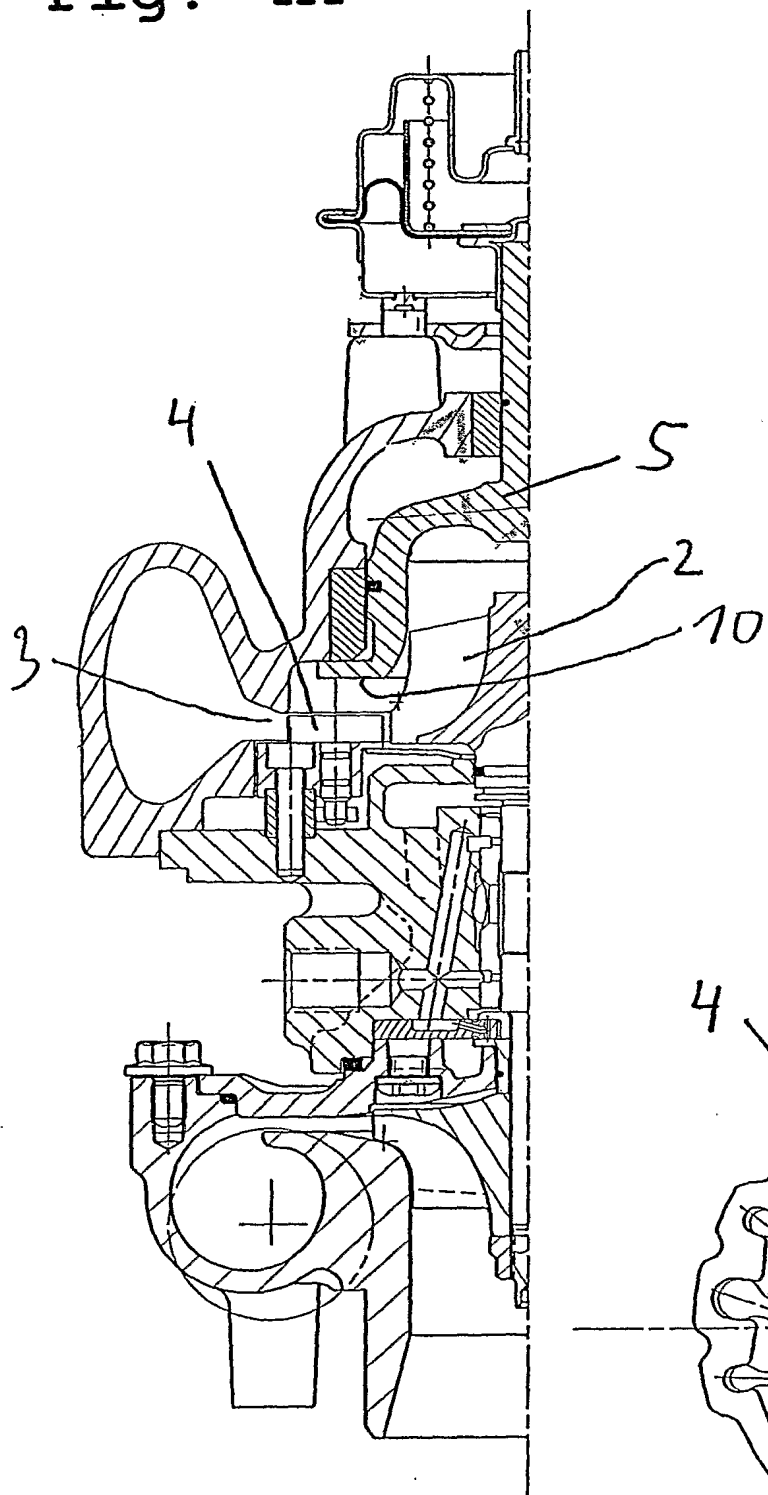


1/2 open

**Fig. 3B**

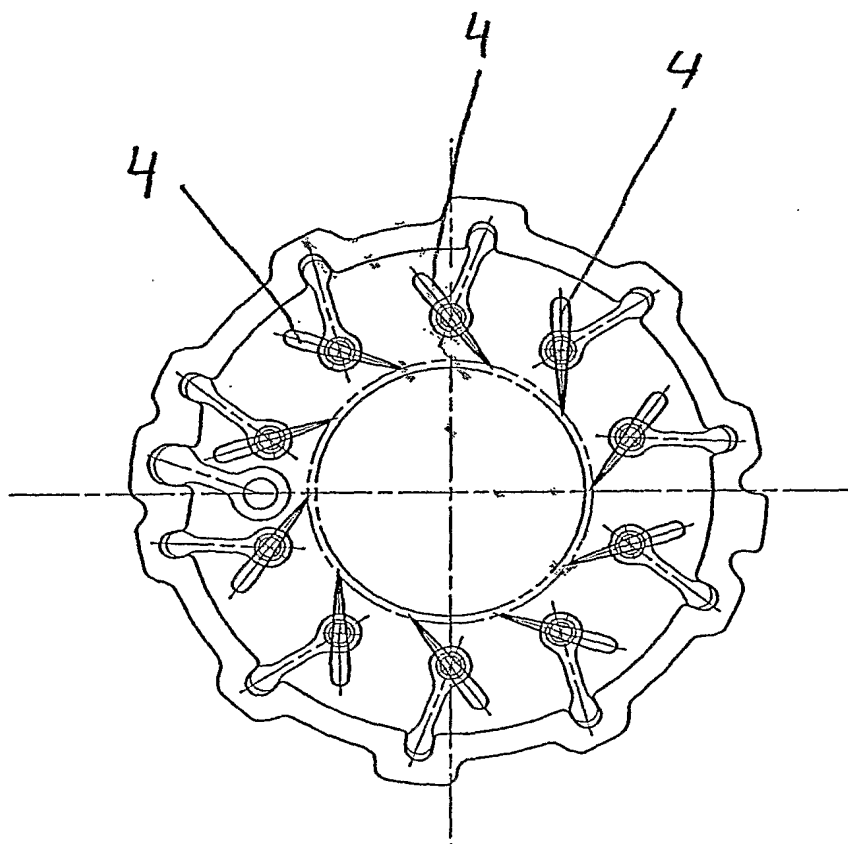


**Fig. 4A**

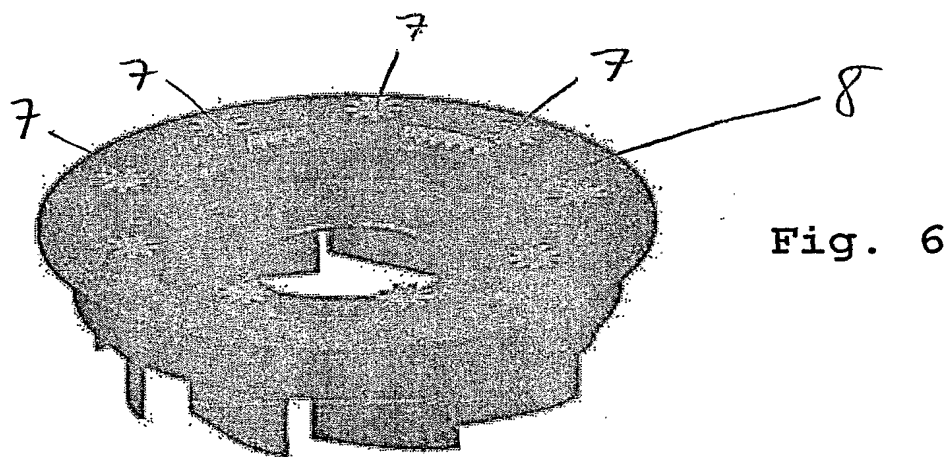
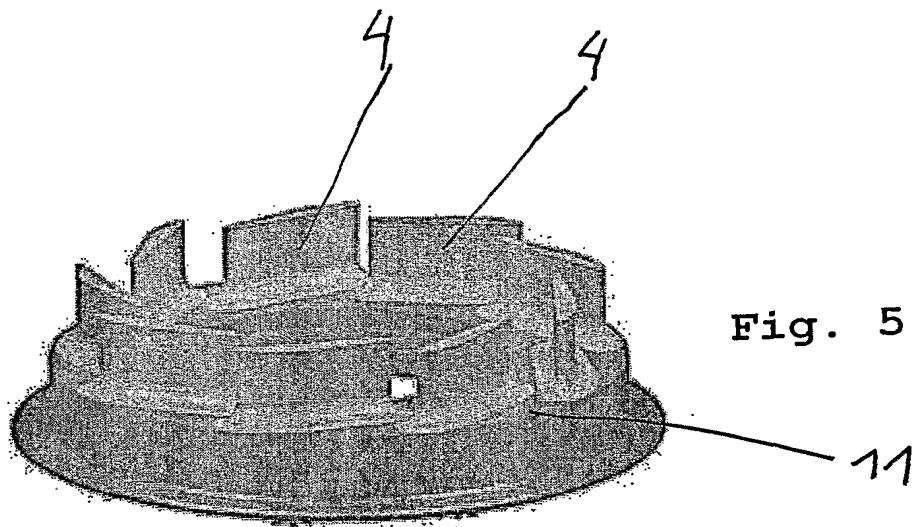


Fully open

**Fig. 4B**







## INTERNATIONAL SEARCH REPORT

International Application No

PCT/IB 02/03834

A. CLASSIFICATION OF SUBJECT MATTER  
 IPC 7 F01D17/16 F01D17/14

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No. |
|------------|--|-----------------------|
| X          | US 6 314 736 B1 (FLEDERSBACHER PETER ET AL) 13 November 2001 (2001-11-13)  | 1-3, 7, 9             |
| Y          | column 2, line 16-18<br>column 3, line 8 - line 16<br>figures 1,2  | 4-6, 8                |
| Y          | US 5 214 920 A (LEAVESLEY MALCOLM G) 1 June 1993 (1993-06-01)<br>column 2, line 21 - line 30<br>column 6, line 37 - line 40<br>column 7, line 39 - line 43<br>figures 6,7,10 | 4-6, 8                |
| A          | WO 02 44527 A (ESPASA OLIVIER ; HONEYWELL GARRETT SA (FR); LOMBARD ALAIN RENE (FR)) 6 June 2002 (2002-06-06)<br>figures  | 1-9                   |
|            | -/--   |                       |

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search

26 May 2003

Date of mailing of the international search report

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Name and mailing address of the ISA

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## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/IB 02/03834

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No. |
|------------|---|-----------------------|
| A          | WO 01 53679 A (VIOLA ERIC JOSEPH<br>;ALLIEDSIGNAL TURBO S A (FR); BERNARDINI<br>LUCIANO) 26 July 2001 (2001-07-26)<br>figure 1<br>--- | 1-9                   |
| X          | US 2 976 013 A (ULRICH HUNTER DAVID)<br>21 March 1961 (1961-03-21)<br>figure 1<br>---   | 1                     |
| A          | US 4 557 665 A (SZCZUPAK DAVID T)<br>10 December 1985 (1985-12-10)<br>column 4, line 33 - line 47<br>figure 2<br>---                  | 1-9                   |
| A          | EP 0 034 915 A (HOLSET ENGINEERING CO)<br>2 September 1981 (1981-09-02)<br>page 2, line 14 - line 20<br>figure 2<br>---               | 1-9                   |
| A          | EP 1 128 025 A (MAN NUTZFAHRZEUGE AG)<br>29 August 2001 (2001-08-29)<br>figure 1<br>---   | 1-3                   |
| X          | GB 138 592 A (BBC BROWN BOVERI & CIE)<br>6 May 1920 (1920-05-06)<br>figures 1,2<br>---  | 10                    |
| X          | US 4 890 977 A (TREMAINE ERIC ET AL)<br>2 January 1990 (1990-01-02)<br>figure 1<br>-----  | 10                    |

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-9

Variable nozzle device for a turbocharger and method for operating a variable nozzle device

2. Claim : 10

Vane pivoting mechanism

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/IB 02/03834

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/IB 02/03834

| Patent document<br>cited in search report |    | Publication<br>date | Patent family<br>member(s)  | Publication<br>date  |
|---|----|---------------------|---|--|
| US 6314736                                | B1 | 13-11-2001          | DE 19961613 A1<br>EP 1111196 A2   | 19-07-2001<br>27-06-2001   |
| US 5214920                                | A  | 01-06-1993          | US 5231831 A  | 03-08-1993   |
| WO 0244527                                | A  | 06-06-2002          | WO 0244527 A1<br>AU 2181201 A   | 06-06-2002<br>11-06-2002   |
| WO 0153679                                | A  | 26-07-2001          | WO 0153679 A1<br>AU 3053800 A<br>CA 2397445 A1<br>EP 1247012 A1                 | 26-07-2001<br>31-07-2001<br>26-07-2001<br>09-10-2002               |
| US 2976013                                | A  | 21-03-1961          | NONE  |  |
| US 4557665                                | A  | 10-12-1985          | DE 3377587 D1<br>EP 0095853 A1  | 08-09-1988<br>07-12-1983   |
| EP 0034915                                | A  | 02-09-1981          | BR 8101054 A<br>EP 0034915 A1<br>ES 8205932 A1<br>JP 56129705 A<br>PL 229827 A1 | 25-08-1981<br>02-09-1981<br>01-11-1982<br>12-10-1981<br>18-09-1981 |
| EP 1128025                                | A  | 29-08-2001          | DE 10009099 A1<br>EP 1128025 A2   | 30-08-2001<br>29-08-2001   |
| GB 138592                                 | A  | 06-05-1920          | NONE  |  |
| US 4890977                                | A  | 02-01-1990          | NONE  |  |